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Biomonitoring of lead, cadmium and chromium in environmental water from Kolkata, North and South 24-Parganas using algae as bioreagent

Nabanita Chakraborty*, Anupam Banerjee, Ruma Pal

Department of Botany, University of Calcutta, 35, Ballygunge Circular Road
Kolkata-700 019, India;

Abstract:

Water and algal samples were collected from different agricultural, industrial and residential areas of Kolkata, North and South 24 Parganas of West Bengal. Heavy metal contaminants like lead (Pb), cadmium (Cd) and chromium (Cr) were measured from both algal flora and their habitat water samples to understand the efficacy of different algal genera in biomonitoring and bioremoval of these metals. Entire study area was found to be contaminated mainly with Pb (0.008 to 12.2 ppm) while Cd and Cr were found at very low to below detection level (BDL). *Anabaena*, *Pithophora*, *Spirogyra* and *Chara* accumulated 20 to50 times more Cd, Cr and Pb than that of habitat water of municipal waste of Kolkata. *Oscillatoria* was found to be a good biomagnifier of the metals grown in raw tannery waste accumulating 15 times more Pb than water. *Rhizoclonium*, *Ulva* and *Catenella* also accumulated Pb from coastal water of Kakdweep in South 24 Parganas

* *Corresponding author: e-mail: naboris2003@yahoo.com*

Introduction:

Pollution of surface water by industrial processes is a widespread and very serious environmental issue. Heavy metals are discharged as main industrial waste in lakes, rivers and agricultural lands. Use of Cd, Cr, and Pb in electroplating factory, plastic industry and in alloy preparation are quite common (Wase and Forster, 1997). Among these most of the Pb comes to the water by discharging sewages from steel plant, leather industry and chemical plants (Sheng et al., 2004). Hexavalent chromium compounds are used in metal plating industry, cooling tower water treatment plant, leather processing etc. (Nriagu, 1988, Donmez, 2002). Lead is extremely toxic and can damage the nervous system, kidney, and reproductive system of animals.

Removal of metal contaminants from waste water and ground water is the first step in an ecological restoration process. Several technologies for treating contaminated wastewater, such as precipitation, solvent extraction, and membrane processes, have been utilized since long back. However, these methods have many disadvantages like incomplete metal removal, toxic sludge generation and cost inefficiency (Brauckmann, 1990; Volesky, 2001). Since few decades the potential of micro algae in metal biosorption process has been studied extensively due to their ubiquitous occurrence in nature (Gekeler et al., 1998). Many algal genera are found to have capabilities to accumulate heavy metals, thereby reducing their toxic effects (Huang et al., 1990; Kuyucak and Volesky, 1990; Schiewer and Volesky, 2000; Satirog˘lu et al., 2002; Arıca et al., 2004; Selatnia et al., 2004).

Kolkata has an area of 185 km^2 and continuously expanding its area day by day. Large numbers of industries that have recently been grown up in and around the city are causing toxic metal exposure to aquatic biota. Moreover, disposal of municipal wastes and city sewage water of both industrial and domestic origin are also causing harmful effect to the ground water as they contain considerable amount of biodegradable and non biodegradable materials including toxic metals. Metals get accumulated in biological systems slowly and also get magnified biologically in various organism of higher trophic order. In the present study a survey work was taken for different industrial and residential areas of Kolkata, North and south 24-Parganas for detecting the heavy metal contaminants like Pb, Cd, and Cr from habitat water and algal samples of twenty one sampling sites to understand the role of different algal genera in biomonitoring and bioremoval processes of these metals.

Study Area

For convenience in data representation the entire study area was subdivided into three zones as follows (Fig. 1):

Zone:1- Kharibari (i), Deganga (ii), Mulipur (iii), Baduria (iv), Basirhat (v), Hasnabad (vi) and Gopalpur (vii) areas of North 24 Parganas.
This zone is mainly residential area surrounded by agricultural fields and ponds. Besides a major textile mill and a rubber factory near Barasat town, there are many small industries in and around these areas.

Zone:2- Baguiati (viii), Kestopur (ix), Dum Dum Park (x), Lake Town (xi) along the Bagjola Khal drainage, tannery stabilisation pond (xii) and tannery raw waste drainage (xiii) of Tiljala area near Eastern Metropolitan bypass, Kolkata.
Tiljala area lies in eastern Kolkata and is contaminated by tannery waste of the

entire 'Charma nagari' of Kolkata metropolitan. About 34 small-scale secondary lead smelters operate here. Many leather, stone, fertilizer and pesticide plants and paint industries are situated near by this area to contribute to the tannery waste. There are a number of ponds, wetlands, fallow lands. A number of factories are set up and a large number of small scale industries are set up without any planning in this area. Kestopur area is situated in the northern part of Kolkata. It is mainly residential area with highly dense population. This area highly contaminated with municipal and domestic waste. A few numbers of automobile workshops are situated here. Effluents from these workshops are also responsible for heavy metal contamination.

Zone:3- Pailan (xiv), Amtala (xv), Mohanpur (xvi), Fatehpur (xvii), Bunorhat (xviii), Kamarhat (xix), Kakdweep (xx) and Diamond Harbour (xxi) areas of South 24 Parganas.

Kakdweep and Diamond Harbour are the south-eastern coastal areas of West Bengal. Diamond harbour is a small city situated beside the river Ganges just before it reaches the sea. Kakdweep is situated almost in the coast of Bay of Bengal. There are some small industries in Pailan, Amtala and Mohonpur area. Fatepur and Kamarhat areas are surrounded by agricultural fields and fish ponds. Some places of this area are densely populated.

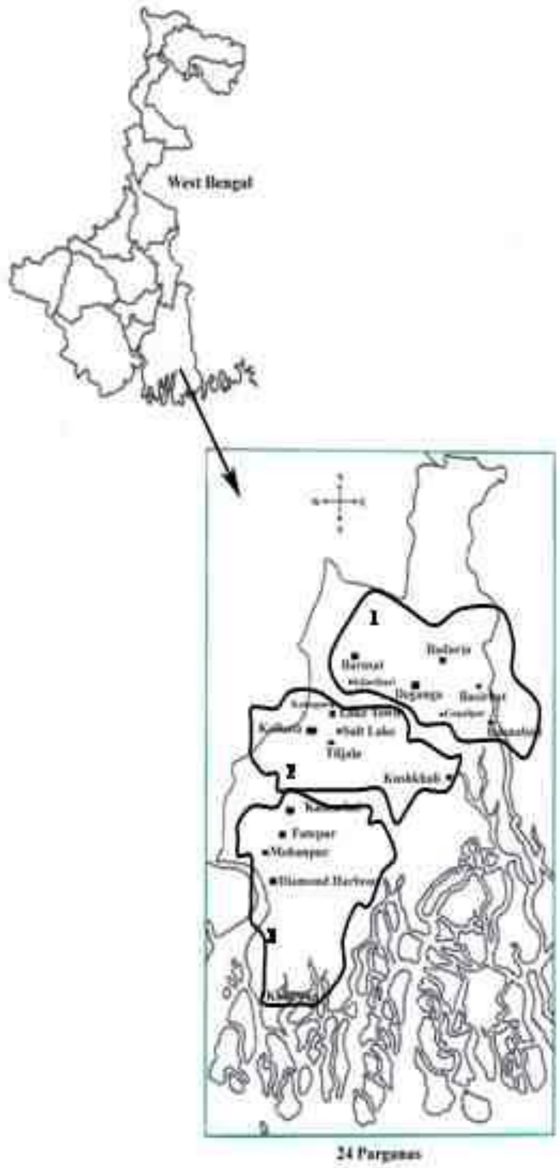

Fig. 1: Study area in and around Kolkata

Materials and methods:

Algal and water samples were collected from different sites. Water samples were preserved with dilute HNO_3. Different algal genera present in the collected samples were identified using proper monographs (Desikachary 1959, Prescott 1982, Krishnamurthy 2000) and are tabulated in the Table 1, 2 and 3. A portion of the algal samples are dried in oven and preserved for analyzing metal content.

Metal content in the sample was studied with the help of Atomic Absorption Spectroscopy (Varian Techtron AA-575 ABQ). Pre weighted dried algal sample was taken and digestion was carried out with concentrated HNO_3 followed by concentrated HCl in digestion flask. The digested algal material was filtered through Whatman-41 filter paper. Final volume of the filtrate was made to 20 mL with double glass-distilled water and taken for spectroscopic study. Similarly the water sample was evaporated to dryness and treated with concentrated HNO_3 and HCl respectively. All the experimental samples were compared with the respective standards of Pb, Cd and Cr.

Results and Discussions:

Metal content of water samples of the study area and their respective algal flora are represented in Tables 1-3. In Zone-1 Mulipur, Baduria, Basirhat and Gopalpur areas are contaminated mainly with Pb. In these areas 1 to 2.2 ppm Pb was recorded from habitat water maximum being at Basirhat region (Table 1) though Cd contamination was comparatively less (0.055 to 0.115 ppm). Basirhat and Gopalpur areas of this zone were found to be contaminated with Cr as well where 0.3 and 0.35 ppm Cr was found in habitat water of respective areas. Metal contamination in these areas is due to release of wastes from small scale factories without proper treatment plant. Kharibari and Deganga areas were found to be free of metal contaminants, being situated far away from the small scale industrial area.

Table 1: Concentration of metals in habitat water and dominant algal genera found in different places of Zone 1

Zone	Site No	Areas	Metals in water (ppm)			Dominant algal genera
			Pb	Cd	Cr	
1	1	Kharibari	BDL	BDL	BDL	*Enteromorpha*
	2	Deganga	BDL	BDL	BDL	*Spirogyra*
	3	Mulipur	1.40	BDL	BDL	*Rhizoclonium* and *Lyngbya*
	4	Baduria	1.25	0.095	BDL	*Anabaena, Spirogyra, Nostoc*
	5	Basirhat	2.2	0.105	0.3	*Pithophora* and *Spirogyra*
	6	Hasnabad	BDL	0.055	BDL	-
	7	Gopalpur	1.75	0.115	0.35	*Chara, Oedogonium, Rhizoclonium*

Metals were found to be bioconcentrated by preferential accumulation and biomagnifications by different algal genera in many places. In Baduria *Anabaena spherica* accumulated twenty times more Cd than that in the water (Fig. 2a). In Basirhat area a mixed algal population of *Pithophora oedogoniana* and *Spirogyra crassa* accumulated almost twenty five times more Cd and almost fifty times more Cr (Fig. 2b). Algal population of Gopalpur area was represented mainly by green algae like *Chara*, *Oedogonium* and *Rhizoclonium* showing twenty times more Pb in *Chara zeylanica* and fifteen times more Cd in *Rhizoclonium riparium* (Fig. 2c).

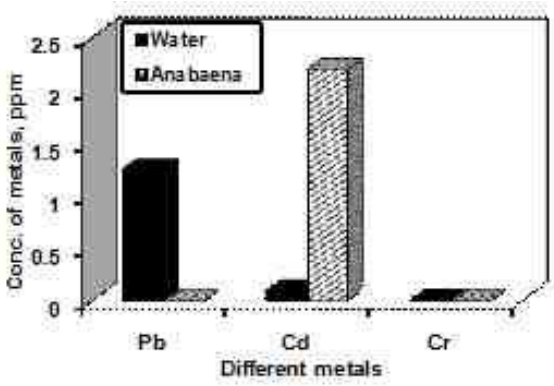

Fig. 2a

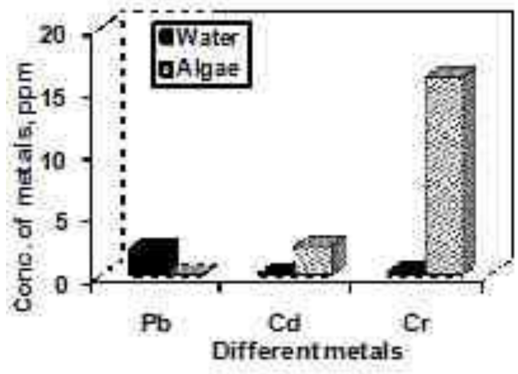

Fig. 2b

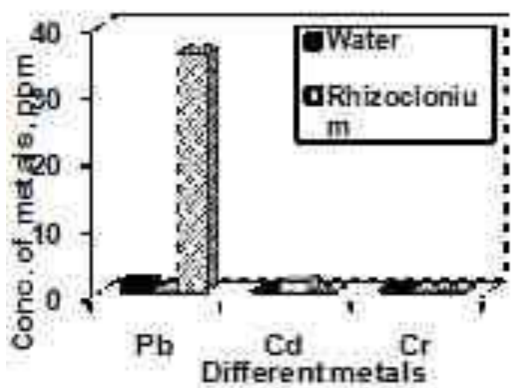

Fig. 2c

Fig. 2 Metal content in algae and water samples of different study areas of Zone 1 (a) Baduria, (b) Basirhat, (c) Gopalpur

Zone 2 was found to be contaminated mostly with Pb. Table 2 reveals that Pb content varied from 0.008 to 0.024 ppm, maximum being in raw tannery waste water. Cadmium and chromium contamination was recorded only in the water samples of Bagjola Khal drainage near Kestopur (0.0012 ppm Cd) and raw tannery waste drainage of Tiljala area (0.4 ppm Cr) respectively

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Table 2: Concentration of metals in habitat water and dominant algal genera found in different places of Zone 2

Zone	Site No	Areas	Metals in water (ppm)			Dominant algal genera
			Pb	Cd	Cr	
2	8	Baguiati	0.01	BDL	BDL	*Oscillatoria*
	9	Kestopur	0.014	0.0012	BDL	*Oscillatoria*
	10	Dum Dum Park	0.01	BDL	BDL	*Oscillatoria*
	11	Lake Town	0.008	BDL	BDL	*Oscillatoria*
	12	Tannery stabilization pond	0.008	BDL	BDL	*Oscillatoria*, *Phormidium*, *Spirulina*, phytoplanktons
	13	Tannery waste drainage	0.024	BDL	0.4	*Oscillatoria*, *Phormidium*, *Spirulina*, phytoplanktons

The only cyanobacterial genus *Oscillatoria* was recorded from sampling sites viii to xi of this zone. The Bagjole Khal drainage passing through these areas was highly contaminated with oil effluents of an automobile factory situated near Kestopur area thereby producing *Oscillatoria* bloom. *Oscillatoria* samples collected from DumDum Park area showed maximum accumulation of 0.136 ppm of Pb, which is fourteen times more than that of water samples (Fig. 3a). Chromium contaminated tannery area showed the population dominated by *Oscillatoria*, *Phormidium*, *Spirulina* and mixed population of several phytoplanktons belonging to cyanophyceae, chlorophyceae and bacillariophyceae. In this area Pb and Cr content of algal samples were much more in comparison to water samples signifying biomagnifications (Fig. 3b, 3c).

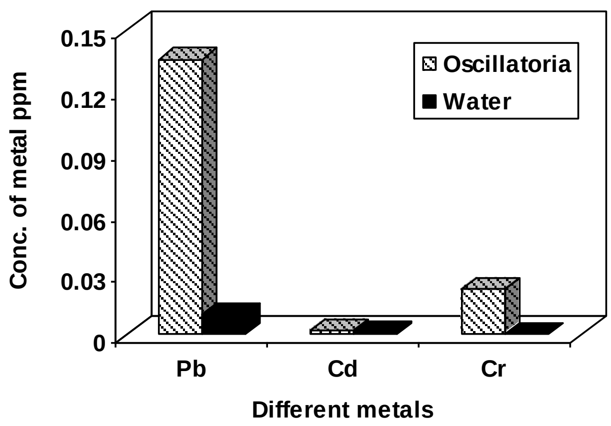

Fig. 3a

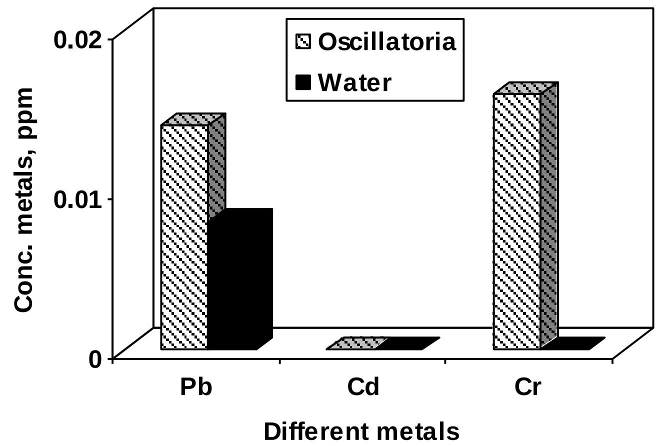

Fig. 3b

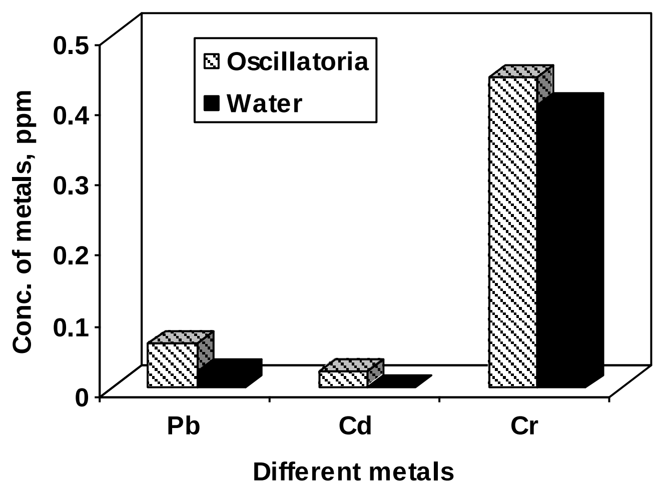

Fig. 3c

[Fig. 3 Metal content in algae and water samples of different study areas of Zone 2 (a) Bagjola Khal drainage near Dum Dum Park, (b) tannery stabilization pond, (c) tannery raw waste drainage

Rhizoclonium. In the coastal belt Kakdweep showed the population of *Ulva* and *Catenella* along with *Rhizoclonium riparium*, whereas, a mixed population of phytoplanktons was recorded together with *Rhizoclonium* in Diamond Harbour.

Water samples of entire study area of this zone was also contaminated with Pb. High Pb contamination (12.25 ppm) was observed in Kamarhat area whereas 0.03 to 0.05 ppm Cd was found in water samples of Mohanpur, Fatehpur and Kamarhat area (Table 3).

Table 3: Concentration of metals in habitat water and dominant algal genera found in different places of Zone 3

Zone	Site No	Areas	Metals in water (ppm)			Dominant algal genera
			Pb	Cd	Cr	
3	14	Pailan	BDL	BDL	BDL	-
	15	Amtala	0.900	BDL	BDL	-
	16	Mohanpur	1.15	0.03	BDL	-
	17	Fatehpur	1.25	0.05	BDL	-
	18	Bunorhat	0.750	BDL	BDL	*Phormidium*, *Lyngbya*
	19	Kamarhat	12.3	0.045	BDL	*Spirogyra and Anabaena*
	20	Kakdweep	0.02	0.002	BDL	*Rhizoclonium*, *Ulva* and *Catenella*
	21	Diamond Harbour	0.08	BDL	BDL	*Rhizoclonium* and phytoplanktons

In Kamarhat area *Spirogyra sp.* accumulated 3 times more Pb than corresponding water sample and 48 times more Cd was accumulated by *Anabaena sp.* than that in the water (Fig. 4a). Moreover, *Rhizoclonium riparium* in Diamond Harbour area and a mixed population of of *Rhizoclonium*, *Ulva* and *Catenella* in Kakdweep area are responsible for biomagnification of Cd and Pb (0.05 mg/g biomass) respectively (Fig. 4b, 4c).

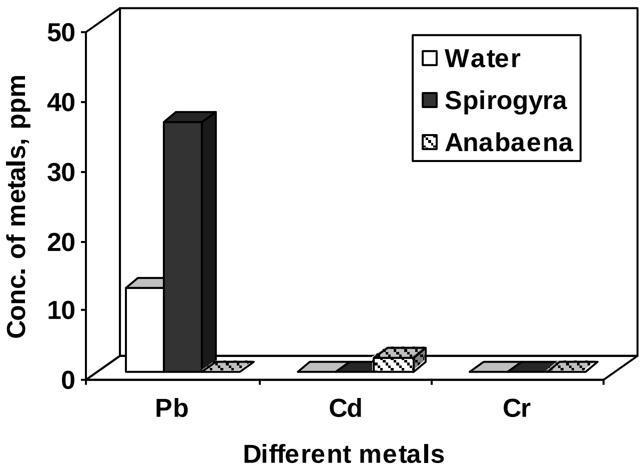

Fig. 4a

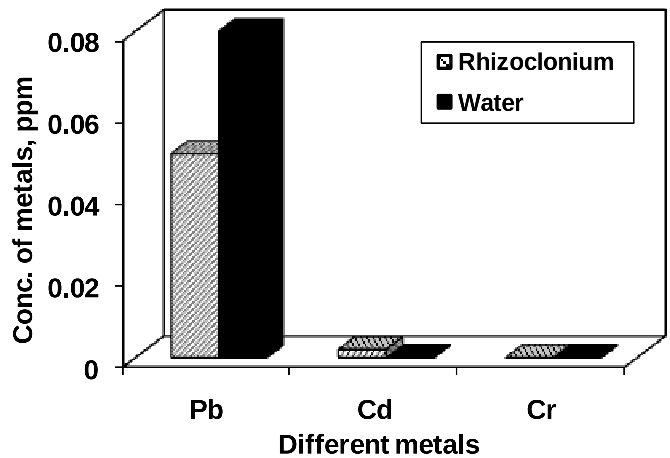

Fig. 4b

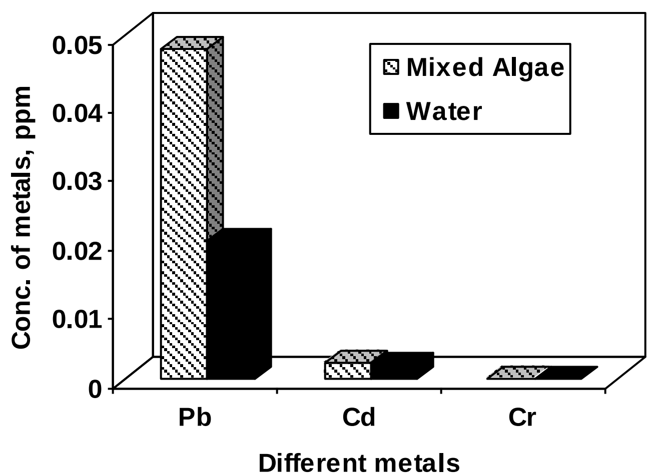

Fig. 4c

Fig. 4 Metal content in algae and water samples of different study areas of Zone 3

(a) Kamarhat, (b) Diamond Harbour, (c) Kakdweep

Reports are available regarding lead content of natural algal population. Denny and Welsh (1979) studied Pb content of three lakes and observed that diatom genus *Melosira* dominated plankton population accumulated more Pb (722 ug/g tissue) than the population dominated by *Asterionella*. Harding and Whitton (1981) reported Zn and Pb content of *Nitella flexilis* from Pb contaminated reservoir polluted by mining activities. *Cladophora glomerata* has also been reported as good accumulator of metals like Pb, Cd, Cu and Zn from lake Ontario (Keeney et al., 1976) and other radioisotopes (Kulikova, 1960; Angelovic, 1965 and Williams, 1970).

Therefore from the above discussion it becomes clear that huge areas of Kolkata and 24 Parganas are contaminated with heavy toxic metals and are dominated by a large number of hyper-accumulator and metal resistant algal genera like *Oscillatoria*, *Anabaena*, *Rhizoclonium* and *Chara*. In one hand these algal genera are suitable for growing in these areas of meso and eutrophic nature for metal bioremediation purpose, on the other hand indicating the risk factor for biomagnification of those metals contaminating the entire food web as fish culture ponds are maintained in many of these areas.

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